THE BIOMEDICAL ENGINEERING PROGRAM OF THE NATIONAL ACADEMY OF ENGINEERING

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THE NATIONAL ACADEMY OF ENGINEERING

THE National Academy of Engineering (NAE) is a part of the corporate structure of the National Academy of Sciences. Founded during the Civil War when Abraham Lincoln was president, the National Academy of Sciences (NAS) is a private, nonprofit organization dedicated to the furtherance of science and its uses for the general welfare. Its Congressional Charter requires that "the Academy shall, whenever called upon by any Department of the Government, investigate, examine, experiment, and report upon any subject of science or art. . . ." The National Academy of Sciences is not an agency of the United States government.

The National Academy of Engineering was established in December 1964 under the charter of the NAS. It is autonomous in its administration and in the selection of members, and shares with the NAS a responsibility for advising the federal government. It is responsible for the conduct of its programs and for the issuance of reports pertaining to those programs.

During the period 1960 to 1964, discussions were held by representatives of the Engineers Joint Council, Engineers' Council for Professional Development, Engineering Foundation, and the National Academy of Sciences, and it was concluded that in the interest of the national welfare the engineer should be more visible and vocal on the national scene to permit him to apply more effectively the competence of the profession to the solution of national problems. The Articles of Organization and Bylaws of the National Academy of Engineering

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were adopted on December 10, 1964, with the following objectives and purposes:

1) to provide means of assessing the constantly changing needs of the nation and the technical resources that can and should be applied to them, to sponsor programs aimed at meeting these needs, and to encourage such engineering research as may be advisable in the national interest;

2) to explore means for promoting cooperation in engineering in the United States and abroad, with a view to securing concentration on problems significant to society and encouraging research and development aimed at meeting them;

3) to advise the Congress and the executive branch of the government, whenever called upon by any department or agency thereof, on matters of national import pertinent to engineering;

4) to cooperate with the National Academy of Sciences on matters involving both science and engineering;

5) to serve the nation in other respects in connection with significant problems in engineering and technology; and

6) to recognize outstanding contributions to the nation by leading engineers.

Financial support for the National Academy of Engineering is provided by private and public contributions, grants, and contracts, and through the voluntary contributions of time and effort by many of the nation's leading scientists and engineers. The Engineering Foundation provided financial support during the planning phase, and initial operations of the National Academy of Engineering were supported through an unrestricted grant of $100,000 made by the Alfred P. Sloan Foundation in July 1965.

A person is qualified as a candidate for membership in the National Academy of Engineering if he himself has made identifiable contributions or accomplishments in one or both of the following categories: 1) important contributions to engineering theory and practice, including significant contributions to the literature of engineering; and 2) demonstration of unusual accomplishments in the pioneering of new and developing fields of technology. New members are elected annually to the National Academy of Engineering; the total membership is now 279.

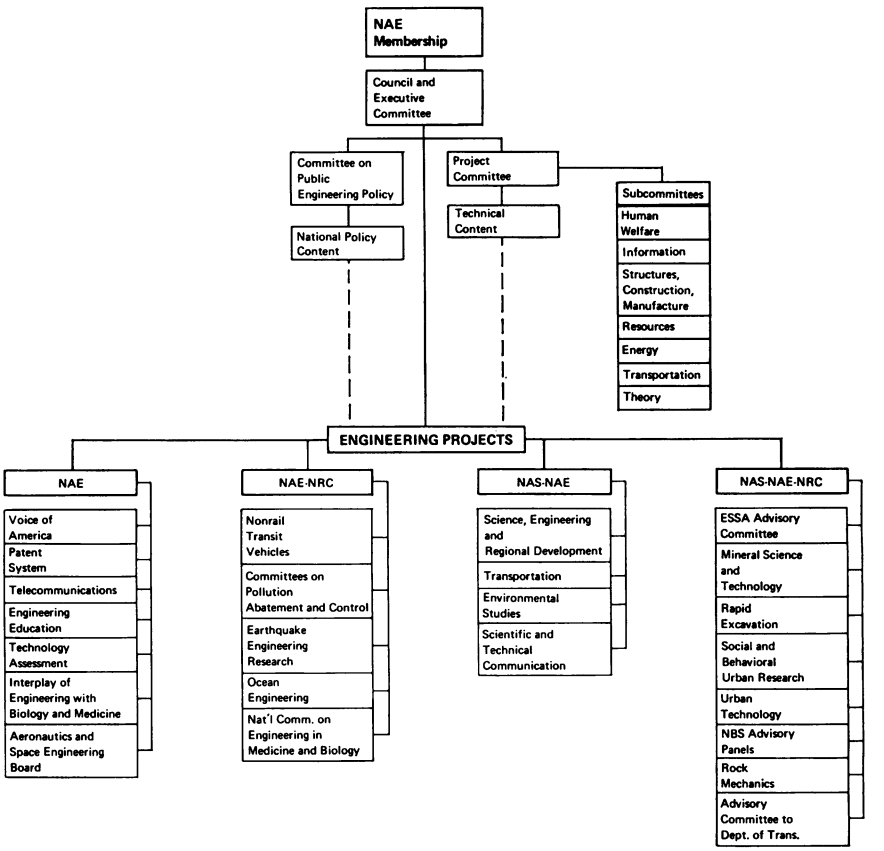

Fig. 1. The National Academy of Engineering.

The National Research Council

The National Research Council is an agency organized in 1916 by the National Academy of Sciences to enable the broad community of scientists and engineers of the United States to associate their efforts with those of the more limited membership of the Academy in service to science and the nation. Many of the activities undertaken by the two academies are carried out through the National Research Council.

Organization of the National Academy of Engineering

The president of the NAE is Eric A. Walker, who took office in April 1966. His term will expire in 1970. The president is the chief ex-

ecutive officer of the Academy and, with the Council, directs the general business of the Academy. The president of the NAE receives no monetary compensation for this position.

The National Academy of Engineering has permanent committees to deal with its organization, administration, and membership. Additionally, there are a number of committees to implement NAE plans and programs, and to discharge responsibilities of the Academy to the government and to the nation. The operational structure of the NAE is shown in Figure 1. The NAE is involved in a wide variety of important technological projects, which range from rock mechanics to the interplay of engineering with biology and medicine.

The Committee on the Interplay of Engineering with Biology and Medicine

The Committee on the Interplay of Engineering with Biology and Medicine (CIEBM), under the chairmanship of John G. Truxal, institute professor, Polytechnic Institute of Brooklyn, is one portion of the NAE's program concerned with the role of technology in the improvement of health care and medical services. Established in 1967 on the basis of a contract from the National Institutes of Health, the Interplay Committee is attempting to develop guidelines and recommendations for the improved interaction and cooperation of government, industry, and academic institutions in biomedical engineering. The broad purpose of the committee is to delineate clearly characteristics and limitations of modern engineering and the means by which the national engineering capability can be effectively directed toward the fundamental and applied problems of concern to the National Institutes of Health.

During its first year of activity the committee began an examination of engineering in biology and medicine in the following broad areas:

The role and extension of engineering concepts and technology in the scientific inquiry into biological phenomena as a basis for advancing the understanding of biological systems.

The utilization of engineering concepts and technology in the development of instrumentation, materials, diagnostic and therapeutic devices, artificial organs and other constructs relevant to the solution of major problems in the areas of biology and medicine.

The application of engineering concepts and theory to the de-

velopment and further evolution of social systems and such micro-representations of social systems as hospitals or related health service units.

The committee thus far has focused on three major efforts:

1) Subcontracts were awarded to the University of Virginia, Ohio State University, Carnegie-Mellon University, Johns Hopkins University, University of Washington, and MIT-Harvard University for specific studies of various ways in which university-industry-government-community cooperation can be developed to enhance the contributions of biomedical engineering—an expanded application of technology —to a more effective delivery of health and medical services. These six studies, along with parallel, independent studies at other institutions, were summarized at a meeting on October 29, 1968 at the Academy. The primary objective of this committee project is to develop prototype plans for bringing together the engineering and medical competencies in a geographic region to permit the biomedical engineering programs of universities and of industry to focus on specific needs. A report has been made on this project and is entitled *Prototype University Plans for the Development of Biomedical Engineering.*

2) Subcommittees of the CIEBM are considering particular areas of biomedical engineering: the status of the area, the needs for the immediate future, and the bases on which the required research, development, and production can be stimulated. Active subcommittees are now considering sensory aids, instrumentation for surgery, and multiphasic health-screening systems. In addition, the committee is attempting to consider the factors which lead to a favorable environment for biomedical engineering in several other countries.

3) The Subcommittee on Interaction with Industry is currently initiating a series of small conferences with representatives of industrial organizations directly involved in biomedical engineering in order to obtain an understanding of the factors considered by industry to be of importance to the future development of the field.

Committee action during the initial year of activity has provided a broad base of data for future directions of study—in particular: 1) a consideration of the difficult, basic problems connected with influencing the development phase in medicine and biology; 2) an evaluation of the limitations imposed on engineering in this field by the existing social and economic environment into which new products are introduced; and 3)

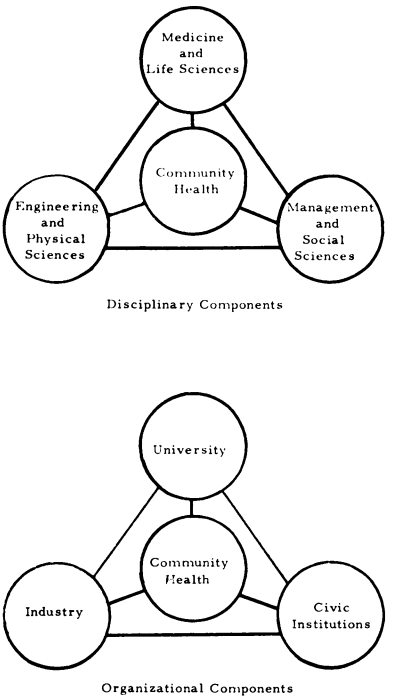

Fig. 2. Disciplinary and organizational components for health services.

the preparation of recommendations to reduce the constraints resulting from the academic separation of engineering and biomedical fields and the present privately-based medical care system.

Prototype Institutions in the Future Development of Biomedical Engineering

The task of advancing biomedical research and securing the effective utilization of modern science and technology in the provision of health services and medical care is the collaborative responsibility of certain disciplinary and organizational components, as illustrated by Figure 2. Both models show clearly that an enormous community effort is required to interact in order to provide for the health of the community. A major objective of the study, then, was to show how to couple more effectively the disciplinary and organizational components so that they can work together in the application of advanced technology to the

urgent problems of community health. The subcontractors were asked to propose prototype concepts for the functional, organizational, and operational relations of university activities in engineering and in the physical, biological, medical, social, and management sciences. They were asked to direct their plans toward ways to secure the most effective interplay of these fields both in the advancement of medical and biological research and in the development of practical solutions to urgent problems in the medical and health-care areas. Consideration also was to be given to the enhancement of training of scientists, engineers, technicians, and instructors to advance multidisciplinary programs. The subcontractors identified industrial and civic resources in the locale of the university that can contribute to exploiting the interplay of engineering, biology, and medicine. They defined problems which are amenable to solution by means of multidisciplinary efforts in this field. Finally, the subcontractors were to develop operational plans aimed at securing the most effective relation among industrial and community elements (Figure 2) which, together with the university, will advance research efforts and obtain the optimum combination of resources directed to the solution of urgent problems in the medical and health care areas in the local setting.

The final report of the CIEBM subcontract studies presents the recommendations made for coupling the several disciplinary and organizational elements in the community to provide for better health of the community. Particular emphasis was given by all of the subcontractors to the need for the university to extend its activities into what might be called the health-service field. In other engineering endeavors this might be called extending their interest to the developmental phase. Much attention was directed to ways that developments from biomedical engineering, research, and educational programs can be communicated effectively to the medical community and to industry to realize the full value of these programs.

Phase II Study Subcontracts

The formal study portion of Phase I ended with a review of the six studies at a special meeting of the CIEBM on October 29, 1968. The report *Prototype University Plans for the Development of Biomedical Engineering* comprises the CIEBM response on this project. Phase I studies provided considerable information on: 1) the constraints result-

ing from the academic separation of engineering and biomedical fields and the present privately based medical care systems; and 2) the limitations imposed on engineering in this field by the existing social and economic environment into which new products are introduced. Phase II, therefore, is for the purpose of developing plans and operational mechanisms by which this information can be obtained. The goal is to implement representative prototype plans of the type produced in Phase I, to gain experience in the participation of industry in the development phase of engineering in biology and medicine. The general objective is to secure the most effective relation among industrial and community elements which, together with the university, will advance research efforts and seek the optimum combination of resources directed to the solution of urgent problems in the medical and health care areas.

Phase II also involves a subcommitte of the CIEBM. The program of the Subcommittee on Interaction with Industry applies directly to the objectives of Phase II. This subcommittee currently is conducting a series of interviews with decision-making personnel in several key industrial firms to learn the basis on which corporate decisions are made when determining whether to proceed in this field. Subcontractors of the Phase II study will maintain close contact with the program of the Subcommittee on Interaction with Industry. A list of issues important to industrial managers has been prepared as a focal point for discussion, and several specialized conferences will be conducted by the CIEBM to consider in depth the important issues highlighted during these interviews. After the specialized meetings a summary conference is planned to examine the important issues in depth and to present them to a wide audience.

Thus we see the development of a two-pronged approach at planning a more effective application of technology to the solution of problems of health. One approach is centered on the university community, the other looks at the problem from the viewpoint of the business community.

Phase III Study Subcontracts

The dynamic nature of biomedical engineering is such that changes in the program are made frequently. Typical of these changes is an awakening in the university of the need for developing organizational arrangements to handle multidisciplinary projects and a tendency for

biomedical engineers to participate more directly in problems concerned with the delivery of health services. The CIEBM believes it important for the Phase I subcontractors to report on the evolution of their biomedical engineering program during 12 months following completion of their initial studies. This will be known as Phase III of the university subcontract project; a final report is to be published in the last quarter of 1970.

Biomedical Engineering in Research and Health Service

After World War II engineers gave increasing attention to the problems of biology and medicine. "Medical electronics" became a popular phrase for engineers to use. This was the time when the models of electronics were considered by physicians and engineers alike as capable of solving many of the problems of medicine. It was the time when relatively simple instruments and devices could be devised by the engineer following a discussion with a physician as to his need of the moment. The engineer rather believed that the expertness of his profession could solve problems of medical research without the need for an understanding in biology; the life scientist felt that books on engineering contained ample information to enable him to apply engineering principles to his problem. As we know, each found subsequently that a good understanding of the other's discipline is essential.

By 1950 social and scientific conditions had converged to permit massive research programs to be launched to seek solutions of health problems. Full recognition was given to the principle that the support of science has a high probability of achieving important breakthroughs in knowledge which, in turn, can be converted into application important to the amelioration of men's lives. Health-related research is of importance in this respect.

Since 1961 the National Institute of General Medical Sciences has supported the Engineering in Biology and Medicine Program which has been notably successful in the production of Ph.D. researchers. The program has concentrated on the development of a strong theoretical base for biomedical engineering. The serious shortage of many qualified people in this field has made it vital to train the basic researchers who can in turn train others.

The elements of research, development, and production form an essential continuum without which any technological system is open-

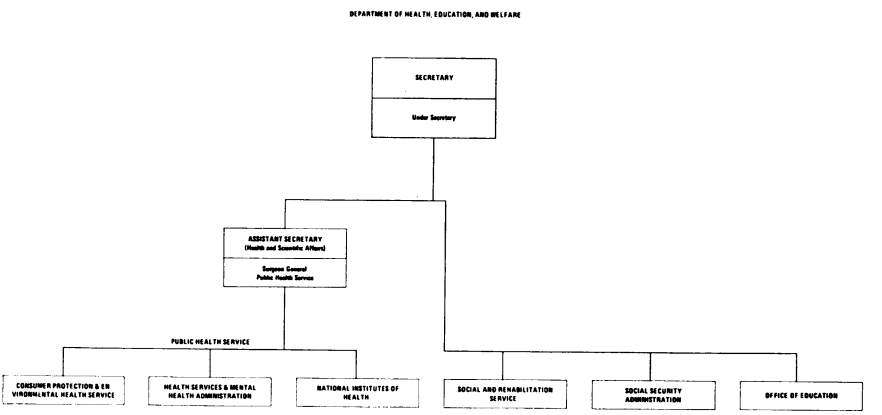

Fig. 3. Reorganized structure of the Department of Health, Education, and Welfare.

ended and incomplete. As mentioned above, the research element has been stressed in programs of grants for biomedical engineering. The other vital elements of the system—development and production—have received comparatively little attention to date. A major reason for this is that the Department of Health, Education, and Welfare (HEW) has conducted few formal programs in biomedical engineering in the development and service elements of the continuum. Two important legislative examples—the Regional Medical Programs and the Partnership for Health authorizations—now permit major demonstrations of conversion to practice of the results-related research. Also, the health agencies within HEW now present *development* and *service* in a sharper focus, as a result of the most recent departmental reorganization. The Health Services and Mental Health Administration includes Regional Medical Programs and the new National Center for Health Services Research and Development; the Consumer Protection and Environmental Health Services includes the Food and Drug Administration and the National Center for Radiological Health. These newest federal health agencies will conduct development programs that have a high technological content.

Deliberations at CIEBM Committee Meetings are concerned increasingly with the two major aspects of the interplay of engineering with biology and medicine: the research component and the (development) service component of the National Health Program. Both components

can benefit from a thorough evaluation of how engineering capabilities can be applied to the solution of pressing health problems. Figure 3 shows the basic reorganizational structure of HEW. The program of the National Institutes of Health is largely directed to the basic research component, while the Health Services and Mental Health Administration, particularly the National Center for Health Services Research and Development, applies its major emphasis to the conduct of technological development programs for the improvement of health services.

As already mentioned, the CIEBM University Study Project has produced tentative recommendations for organizational arrangements to provide for a more effective application of technology to the solution of health problems. A natural sequence to this study would be a consideration of the Health Care Technology program of the National Center for Health Service Research and Development.

Other Subcommittees of the CIEBM

Several subcommittees of the CIEBM are considering particular areas of biomedical engineering: the state of the art in each area, the problem, unique opportunities for the resolution of the problem, obstructions to realization of these opportunities, proposals and benchmarks for implementation, anticipated results, and the time and cost. Active subcommittees are considering Engineering in Surgery and Sensory Aids. Additionally, the CIEBM is considering the factors which lead to a favorable environment for biomedical engineering in several other countries to determine which mechanisms might be adopted to improve the health system of the United States.

The Engineering in Surgery Subcommittee has adopted specific goals. It has:

1) Recommended steps to bring about a more successful integration of engineering and surgery in the areas of (*a*) basic and applied research, (*b*) the development of instruments, devices, and systems, and (*c*) the delivery of health services.

2) Encouraged and facilitated the participation of the academic and industrial engineering community in the programs, meetings, and business of surgical societies.

3) Determined ways of making effective representation at the national level in behalf of biomedical research and development.

The Subcommittee on Sensory Aids is preparing a plan for a na-

tional program to be directed to the pressing problem of bringing benefits to the sensory-deprived, benefits which can stem from our increasing understanding of medical, psychophysical, and physical reality. Both a short-range program of applications and a longer-range program of research will be developed.

Plans for the Future

The National Academy of Engineering's Committee on the Interplay of Engineering with Biology and Medicine currently is making plans to broaden its scope of effort. This action is in response to the NAE Project Committee for the CIEBM to formulate a specific recommendation regarding the long-term role of the NAE in areas of medical and health engineering. As the American public demands more and better health services, the federal interest is likely to be expansionist in nature. There is every reason to believe that the need to apply technology will become more important and that the services of the engineer will be sought more often than is done today.

Engineering capabilities extend beyond the development and production of medical instruments to aid in the solution of health problems. The provision of health care has been little affected by the technological changes that have occurred in other fields. The innovations and technologies of other sectors must be exploited, and new techniques must be developed appropriate to the solution of health problems if the health care system is to respond adequately to social change and scientific advance. The National Academy of Engineering expects to play a leading role in developing the capability of the health system to respond to those changes.